

Original Research Article

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Weed Dynamics, Nutrient Removal and Crop Productivity as Influenced by Weed Management Practices in Direct Seeded Basmati Rice Preceded by Wheat in Irrigated Sub Tropics of Jammu

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ABSTRACT

An experiment was conducted at the Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu under irrigated conditions to assess the efficacy of different weed management practices on weed dynamics, nutrient removal and productivity of direct seeded basmati rice preceded by wheat in a crop sequence of wheat and rice. The most efficient weed control was provided by the application of Pendimethalin @ 1.0 kg/ha (PE) *fb* Bispyrebac @ 0.030 kg/ha (PoE) that resulted in highest Weed Control Efficiencies of 84.01 and 86.05 % favouring highest grain yields of 23.69 and 25.09 q/ha of direct seeded basmati rice correspondingly this treatment recorded maximum and minimum removal of nutrients by crop and weeds, respectively. Nutrient uptake by both crop and weeds was directly influenced by the relative efficacy of weed management treatments.

Keywords

Direct seeded
basmati rice,
Nutrient uptake,
Weed
management,
Weed dynamics.

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Introduction

Rice (*Oryza sativa* L.) is grown in about 114 countries and out of which more than 50 countries have an annual production of about 0.1 million tonnes or more (FAO, 2010). Half of the world's population fulfil its food calories requirement through rice (Farooq *et al.*, 2011). In India, this crop plays an important role in country's food security. Total rice grain production of the country was 106.54 million tonnes from 43.95 million hectares of land registering an average grain yield of 24.24 quintals/hectare (Anonymous,

2014). The Jammu and Kashmir state recorded 4.5 million tonnes of rice grain from an area of 2.71 million hectares with an average of 17.11 quintals/hectare (Anonymous, 2015). Among different rice varieties cultivated in the country, aromatic rice cultivars are the most unique which are relished by the consumers and costlier as compared to other varieties. In Jammu region of the state, the total area under rice is 114 thousand hectares and about 48 thousand hectares of land is under different types of

aromatic rice types and amongst them Basmati-370 is predominant in the region (Anonymous, 2014 b). Basmati rice of Jammu province of the state is known for its export quality earning foreign exchange.

In India, rice and wheat are the staple food crops which provide food security to 77 per cent of the country's population occupying nearly 13.5 million hectares of the Indo-Gangetic plains of South Asia (Singh *et al.*, 2012). In sub-tropical irrigated plains of Jammu basmati rice-wheat is the predominant cropping system.

Growing rice through convention transplanting method requires large quantity of water for puddling and transplanting operations are labour intensive, time consuming and costly. Shortage of water and rising cost of labour are the reasons to seek for an alternative technique to transplanting. Direct seeding offers advantages such as faster and easier planting, reduced labour and drudgery, earlier crop maturity by 7 to 10 days, more efficient use of water, higher tolerance to water deficit, fewer methane emissions and often higher profits in areas with assured water supply (Balasubramanian and Hill, 2002). Direct seeding is also well thought out option for basmati rice cultivation as the crop takes longer growing period under transplanted conditions. Direct seeding is an economical alternative to transplanting rice but weeds are the major constraints to its successful cultivation since emergence and growth of weeds start simultaneously with those of rice. In direct seeded aerobic rice, yield penalty is as high as 50-91% (Rao *et al.*, 2007). The complexity of the situations has resulted in a dire need to develop a holistic weed control programme throughout cropping period of rice and wheat crops which may prove successful and enhance productivity. For successful crop production coordinated weed management strategies including

mechanical and herbicidal weed management interventions must be followed. Weed management interventions control weeds effectively and made available more nutrients to rice crop while lesser to weeds and consequently resulted in higher crop yields (Rana *et al.*, 2000 and Kumar *et al.*, 2010). All these factors affect not only the productivity of crop but also the nutrient uptake by the crop during growth and development. Therefore, in order to achieve higher productivity of direct seeded basmati rice in rice-wheat cropping system there is an utmost need to evolve concrete weed management strategies for direct seeded basmati rice with in the cropping sequence of wheat and rice. Keeping the above facts in view a scientific investigation on Weed dynamics, nutrient removal and crop productivity as influenced by weed management practices in direct seeded basmati rice preceded by wheat in irrigated sub tropics of Jammu was undertaken.

Materials and Methods

An investigation was carried out on direct seeded basmati rice during *kharif* seasons of 2014 and 2015 at Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu. The experimental area was located at 32°-40° N latitude and 74-58° E longitude at an altitude of 332 m above mean sea level in Shivalik foot hill plains of North-Western Himalayan region. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in available nitrogen (242.60 kg/ha) and organic carbon (0.45 %) while medium in phosphorous (12.98 %) and potassium (154.40 kg/ha). The rainfall received during the crop growing periods from *rabi* 2013-14 to *kharif* 2014 was 1160.4 mm while 1494.1 mm of rainfall was received from *rabi* 2014-15 to *kharif* 2015. Initially the experiment started in the previous season of *rabi* 2013-

14, laid out in randomised block design for wheat crop while during *kharif* season of 2014 the layout was converted into split-plot design for direct seeded basmati rice considering weed management approaches of wheat crop as main plot treatments and weed management approaches of direct seeded basmati rice as sub-plot treatments. The weed management treatments of wheat crop comprised of T₁ (Weedy check); T₂ (Mechanical weeding-2 at 30 and 60 DAS); T₃ (Isoproturon @ 1.0 kg/ha + 2,4-D @ 0.500 l/ha -PoE); T₄ (Clodinafop @ 0.060 kg/ha -PoE) and T₅ (Triasulfuron @ 0.015 kg/ha -PoE) whereas in basmati rice each treatment plot of wheat was split into four sub-plots and the weed management treatments of direct seeded basmati rice consisted of W₁ (Weedy check); W₂ (Mechanical weeding-2 at 30 and 60 DAS); W₃ (Pendimethalin @ 1.0 kg/ha -PE); W₄ (Pendimethalin @ 1.0 kg/ha -PE *fb* Bispyrebac @ 0.30 kg/ha -PoE). The variety of basmati rice used in the experiment was Basmati-370. The crop was sown manually in lines 20 cm apart with seed rate of 40 kg/ha. A uniform recommended dose of N (30 kg/ha), P (20 kg/ha) and K (10 kg/ha) through inorganic sources of nutrients *viz.*, Urea, DAP and MOP was applied to all the experimental plots along with other cultivation practices as per the recommended package of practices. Out of the recommended doses 50 % of nitrogen along with full doses of phosphorus and potassium were applied at the time of sowing as basal dose in the direct seeded basmati rice crop.

The remaining 50 % nitrogen was applied in two equal splits at tillering and panicle initiation stage. Mechanical weeding was done twice 30 DAS and 60 DAS in direct seeded basmati rice with in the crop rows with the help of hand operated wheel hoe. Herbicides were applied with the help of Knapsac sprayer fitted with flat fan T-jet nozzle using spray volume of 500

litres/hectare. Pendimethalin @ 1.0 kg/ha was applied as pre-emergence within 24 hours of sowing where as in other treatment Pendimethalin @ 1.0 kg/ha (pre-emergence) was followed by Bispyrebac @ 0.030 kg/ha as post-emergence at 30 DAS. The irrigations were applied as and when hair line cracks were observed on the field to maintain proper soil moisture particularly during active tillering, vegetative and reproductive phases. Plant protection measures were undertaken to maintain proper growth and development of the crop.

Three spots each of one square meter were randomly selected by throwing one square meter quadrant in the net plot. The threshed grains obtained from each net plot were weighed separately and finally converted into q/ha by multiplying with conversion factor given below:

$$\text{Grain yield (q/ha)} = \frac{\text{Yield obtained from net plot (kg)}}{\text{Area of net plot (m}^2\text{)} \times 100} \times 10,000$$

The determination of weed density was done by standard quadrant method given by Mishra and Mishra (1997). Weed population was recorded from quadrant (0.5m x 0.5m) selected at random in each plot from three places which were expressed on per m² basis.

Weeds collected from area 0.5m x 0.5m area were first sun dried for 2-3 days and then were oven dried at 70°C till constant weight was recorded and expressed in g/m². The data obtained were subjected to square root transformation ($\sqrt{x + 1}$) as wide variations existed among the treatments before statistical analysis.

Weed Control efficiency

Weed Control efficiency (WCE) was calculated by using the following formula

given by Mishra and Mishra (1997) and expressed in per cent as:

$$\text{WCE} = \frac{\text{Wd}_c - \text{Wd}_t}{\text{Wd}_c} \times 100$$

Where,

Wd_c = Weed dry weight in control plot (weedy check)

Wd_t = Weed dry weight in treated plot (treatment)

Processing of samples

Treatment wise crop and weed samples obtained at 30 DAS and grain and straw samples of the respective crops taken at harvest were washed first with tap water and then with distilled water. These samples were sun dried for 2-3 days and then in oven dried at 70°C for 24 hours, dried samples were ground in to 40 mesh size.

Uptake studies in crops and weeds

The crop and weed samples were collected at 30 days after sowing and at harvest for the estimation of N, P and K concentration.

The grain of wheat and basmati rice were also taken from each treatment plot.

The N, P and K in grain and straw in wheat and basmati rice as well as in weed samples were calculated by multiplying per cent nutrient content with their respective dry matter as per the formula given below:

Nutrient uptake (kg/ha) =

$$\frac{\text{Nutrient content (\%)} \times \text{Plant dry matter (kg/ha)}}{100}$$

Estimation of total N

The ground plant samples weighing 0.5 gram were digested in the Kjeldahl's flask in concentrated sulphuric acid in presence of a digestion mixture consisting of K_2SO_4 , FeSO_4 and CuSO_4 in the ratio of 20:2:1 and nitrogen was estimated by Kjeldahl's method, (Jackson 1973).

Estimation of P and K

0.5 gram of oven dried plant samples from each treatment, were put in conical flask followed by addition of about 10 ml tri-acid mixture (HNO_3 , H_2SO_4 and HClO_4) in the ratio of 10:4:1 respectively and kept on the hot plate till digested. P and K from the extract were estimated by standard methods (Jackson, 1973).

Results and Discussion

Weed dynamics in direct seeded basmati rice as influenced by weed management treatments preceded by wheat

The impact of different weed management treatments imposed on direct seeded basmati rice preceded by wheat was studied with regard to weed density, weed dry matter and weed control efficiency. The weed flora of the rice field was mainly comprised of narrow leaved weeds (grasses and sedges) including *Cyperus rotundus*, *Cyperus iria*, *Echinochloa colona*, *Echinochloa crusgalli* and *Cynodon dactylon* while *Commelina benghalensis* was the major broad leaved weed of the experimental field of direct seeded basmati rice. The weeds that were of lesser numerical significance in terms of both densities and dry weights were grouped under other weeds included *Convulvulus arvensis*, *Amaranthus sp.*, *Physalis minima*, *Celosia argenticia*, *Phyllanthus niruri* etc. in both cropping seasons of kharif-2014 and 2015.

However, the total weeds were constituted by the sum of individual weed species as well as the other weeds present in the rice crop field in both the years.

All the weed management practices in the main plots that were imposed on preceding crop of wheat had non-significant influence on the total population and dry weight of weeds of present in the plots of direct seeded basmati rice. However, these treatments had significant effect on the weed flora in the previous wheat crop that is not elaborately discussed here as the main focus in this part of investigation is laid on direct seeded basmati rice. After the analysis of the data numerical pattern in the main plots regarding total weed count and dry weight in direct seeded basmati rice was emerged, in the order from minimum to maximum (increasing order) under the corresponding treatments T₃ (isoproturon @ 1.0 kg/ha + 2,4-D @ 0.500 l/ha -PoE); T₂ (mechanical weeding twice at 30 and 60 DAS); T₅ (triasulfuron @ 0.015 kg/ha -PoE); T₄ (clodinafop @ 0.060 kg/ha - PoE) and T₁ (weedy check), respectively.

Perusal of the data presented in table 1 clearly showed that all the weed management treatments in direct seeded basmati rice in the sub plots significantly reduced the total count and dry biomass of the weeds compared to weedy check. Starting from 60 DAS to the subsequent intervals till at harvest, treatment W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE) was significantly superior compared to other treatments in terms of control of weeds with respect to total count and dry weight of weeds, however, sole application of pendimethalin @ 1.0 kg/ha (PE) i.e. treatment W₃ was the next best and statistically at par in reducing total weed density and dry weight of weeds. Both W₃ (pendimethalin @ 1.0 kg/ha-PE) and W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE) were

significantly superior to W₂ (mechanical weeding twice at 30 and 60 DAS) in decreasing infestation of complex weed flora in direct seeded basmati rice. Similar findings were also reported by Badiyala *et al.*, (2014). Pre-emergence application of pendimethalin @ 1.0 kg/ha reduced the initially emerging weeds while the latter flushes of weeds were controlled by the sequential application of bispyrebac @ 0.030 kg/ha. These results are in concurrence to the studies of Walia *et al.*, (2012); Bhurer *et al.*, (2013) and Prasuna and Rammohan (2015). The application of pendimethalin @ 1.0 kg/ha (PE) provided sufficient control of weeds up to 30 days, however, the small number of weeds that emerged in the subsequent flushes were effectively controlled by the post-emergence application of bispyrebac @ 0.030 kg/ha. The pre-emergence application of pendimethalin @ 1.0 kg/ha effectively prohibited the emergence of wide spectrum of weed flora at the very beginning as a consequence the intensity of lately emerged weeds at 30 DAS was not considerably high, in addition to it, the initial advantage gained by the crop over weeds by virtue of early weed control exerted smothering effect on weeds that appeared in the latter stages. Therefore, the plots treated either with alone pendimethalin @ 1.0 kg/ha or pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.030 kg/ha (PoE) in sequence, produced statistically comparable results with regard to reduction in the density and dry matter of total weeds in direct seeded rice crop. These results are akin to the findings of Khaliq *et al.*, (2011) and Awan *et al.*, (2015).

On the other hand, first mechanical weeding was applied by passing wheel hoe at 30 DAS by that time most of weeds had crossed two to four leaf stage due to which there was considerable increase in density and dry matter of weeds. As a consequence of uninterrupted growth of the weeds for 30 days, the initial momentum gained by the

weeds made the weed control by mechanical hoeing very tedious and almost ineffective while the second mechanical weeding at 60 DAS also could not provide a satisfactory control of weeds that emerged subsequently at latter stages. The poor control of weeds by mechanical weedings in DS rice crop is attributed to the fact that uneven soil moisture regimes prevailed during the crop period as the crop was direct seeded and intermittent irrigations were applied as and when the hair line cracks developed on the soil surface, due to frequent wetting and drying the soils developed cloddy surface that was unfit for the use of mechanical wheel hoeing. These findings are in line to the observations of Chauhan (2012). Besides, the weeds that emerged with in the crop rows were not removed while the weeds that were uprooted or slashed by the tine of the rotary wheel hoe between crop rows were not properly buried in the soil as a consequence they regenerated from their vegetative propagules left in the field owing to the conducive soil and environmental conditions of temperature and moisture that facilitated their regeneration. Similar findings were reported by Auld and Kim (1996), Sudhalakshmi *et al.*, (2005), Duary and Mukherjee (2013). However, mechanical weedings at 30 and 60 DAS in DS rice significantly reduced the density and dry weight of weeds compared to weedy check, this finding is in conformity to the works of Pandey (2009) and Kumar *et al.*, (2010).

By and large similar results were obtained in the second year of experimentation with the only difference that all the weed management treatments registered marginal reduction of weeds (in densities and dry weights) while the weed flora was minutely increased under uninterrupted weedy conditions in weedy check plots compared to first year of cropping. This might be due to the less seeds produced by the weeds for the propagation in the succeeding crop since most of the weeds may have been killed before they reach the

stage of maturity. Hence, weed population in these treatments with good weed control may be reduced in the succeeding crop. These outcomes corroborate to the findings of Chang (1972). Interaction effects obtained out of the weed management treatments applied to both wheat and rice were found to be non-significant in terms of total density and dry weight of weeds.

Weed Control Efficiency

Data presented in the table 1, reveals that amongst different weed management practices applied in the direct seeded basmati rice in the experiment, the highest values of weed control efficiencies of 84.01 and 86.05 % were obtained in the treatment W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE) as the sequential application of herbicides provide wider control of complex weed flora in DS rice crop. These results are in consensus to the findings of Kumar *et al.*, (2011); Walia *et al.*, (2011); Brar and Bhullar (2012); Ganai *et al.*, (2014); Mahatale and Patke (2014); Narolia *et al.*, (2014) and Awan *et al.*, (2015).

Influence of weed management treatments on crop yields of direct seeded basmati rice preceded by wheat

The data on grain and straw yields of direct seeded basmati rice as influenced by different weed management treatments depicted in table 1 reveals that all the weed management treatments in the main plots that were imposed on the previous wheat crop had non-significant influence with regard to crop yields of DS basmati rice whereas, these treatments in the earlier crop of wheat significantly influenced crop yields. However, numerical differences were recorded with regard to grain and straw yields of DS basmati rice in decreasing order from maximum to minimum under corresponding treatments T₃ (isoproturon @ 1.0 kg/ha + 2, 4-

D @ 0.500 l/ha -PoE); T₂ (mechanical weedings twice at 30 and 60 DAS); T₅ (triasulfuron @ 0.015 kg/ha -PoE); T₄ (clodinafop @ 0.060 kg/ha -PoE) and T₁ (weedy check), respectively. The relative efficacy of the preceding weed management treatments applied to wheat in the main plots showed their corresponding effect in generating numerical variations on yields of the subsequent DS basmati rice crop.

Different weed management interventions applied in DS basmati rice in the present investigation in sub plots found to cause significant increase in the crop yields (grain and straw) when compared to weedy check.

The corresponding values of grain yields (q/ha) obtained under W₄ (23.69 and 25.09 q/ha); W₃ (21.90 and 23.20 q/ha) against the lowest values of (9.90 and 9.19 q/ha) recorded in W₁ during *kharif* seasons of 2014 and 2015, respectively. On the other hand, the resultant values of straw yield (q/ha) recorded under W₄ (39.21 and 41.12 q/ha); W₃ (36.53 and 40.0 q/ha) and W₁ (17.88 and 17.00 q/ha) during *kharif* seasons of 2014 and 2015, respectively.

The reduction in weed infestation due to the application of different weed management treatments resulted in the reduction in crop-weed competition which in turn favoured production of higher grain and straw of DS basmati rice (Walia *et al.*, 2011 & 2012; Singh, 2012; Longkumar and Singh, 2013; Singh *et al.*, 2014). Application of W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.30 kg/ha -PoE) effected 139.29 and 160.60 % increase in grain yield of DS basmati rice over weedy check. Amongst different treatments applied for the control of weeds in DS basmati rice significantly highest crop yields were recorded under W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.30 kg/ha -PoE) which were however, statistically at par with the alone application

of W₃ (pendimethalin @ 1.0 kg/ha -PE). Application of pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.30 kg/ha (PoE) recorded higher yield and yield attributes of rice, these results corroborate to the findings of Walia *et al.*, (2008 a); Walia *et al.*, (2012) and Brar and Bhullar (2012). On the other hand, sequential application of pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.30 kg/ha (PoE) and the sole application of pendimethalin @ 1.0 kg/ha (PE) recorded statistically equivalent yield attributes and crop yields, these results are in conformation to the findings of Khaliq *et al.*, (2011) according to which the application of pendimethalin *fb* bispyrebac or alone application of pendimethalin recorded statistically similar yield attributes, biological yield and comparable grain yields of 2.58 and 2.48 t/ha, respectively. Similar findings have also been reported by Awan *et al.*, (2015). The pre-emergence application of pendimethalin @ 1.0 kg/ha and the sequential application of pendimethalin @ 1.0 kg/ha (PE) which was followed by bispyrebac @ 0.030 kg/ha (PoE) were significantly superior to the treatment of W₂ (mechanical weedings twice at 30 and 60 DAS) in recording higher yields and yield attributes of the rice crop. These results are in concurrence to the findings of Badiyala *et al.*, (2014) and Kumaran *et al.*, (2015).

The reasons attributed to these outcomes are that the pre-emergence application of pendimethalin @ 1.0 kg/ha caused significant reduction in the initial flushes of emerging weeds which provided initial advantage to the crop over weeds as a result the crop-weed competition was markedly reduced leading to higher yield attributes that culminated into increased grain and straw yields. The subsequent flushes of weeds were controlled by sequential application of bispyrebac @ 0.030 kg/ha at 30 DAS which further had a supplemental effect on the yield contributing characteristics leading to higher crop yields.

Table.1 Effect of weed management practices on weed dynamics, grain and straw yields of Direct seeded basmati rice preceded by wheat

Treatment	Weed count (m ²)		Weed dry weight (g/m ²)		WCE (%)		Grain yield (q/ha)		Straw yield (q/ha)	
	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂
Weed management in wheat										
T ₁	11.85 (139.47)	12.08 (144.87)	10.26 (104.33)	10.54 (110.17)	0.00	0.00	16.73	17.00	27.84	26.73
T ₂	10.92 (118.35)	10.85 (116.62)	9.56 (90.84)	9.45 (88.29)	12.93	19.86	16.96	17.91	29.00	31.17
T ₃	10.68 (113.12)	10.65 (112.39)	9.33 (86.48)	9.26 (84.67)	17.11	23.15	17.23	17.95	30.00	31.53
T ₄	11.56 (132.62)	11.39 (128.67)	10.08 (100.70)	9.95 (98.07)	3.48	10.98	16.82	17.78	28.27	29.85
T ₅	11.24 (125.32)	11.15 (123.34)	9.70 (93.13)	9.64 (91.89)	10.74	16.59	16.9	17.90	28.70	30.04
SE m (±)	0.46	0.44	0.34	0.38			0.37	0.98	1.23	1.89
LSD (p=0.05)	NS	NS	NS	NS			NS	NS	NS	NS
Weed management in rice										
W ₁	15.97 (254.09)	16.29 (264.49)	14.64 (213.34)	14.83 (220.62)	0.00	0.00	9.90	9.19	17.88	17.00
W ₂	11.66 (134.92)	11.40 (129.03)	9.58 (90.72)	9.41 (87.55)	57.48	60.32	12.22	13.35	21.41	21.65
W ₃	7.99 (62.90)	7.78 (59.57)	6.59 (42.41)	6.37 (39.57)	80.12	82.06	21.90	23.20	36.53	40.00
W ₄	7.43 (54.14)	7.22 (51.13)	5.93 (34.12)	5.64 (30.77)	84.01	86.05	23.69	25.09	39.21	41.12
SE m (±)	0.46	0.38	0.33	0.28			0.47	0.59	1.00	0.96
LSD (p=0.05)	1.43	1.22	0.99	0.84			1.83	1.91	3.01	2.88
Interaction										
Factor B at same level of A	NS	NS	NS	NS			NS	NS	NS	NS
Factor A at same level of B	NS	NS	NS	NS			NS	NS	NS	NS

Figures in the parenthesis are original values subjected to $\sqrt{x+1}$ square root transformations

Table.2 Effect of weed management practices on NPK uptake by direct seeded basmati rice at 30 DAS preceded by wheat

Treatment	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂
Weed management in wheat						
T ₁	17.29	17.24	8.17	8.52	16.02	15.74
T ₂	18.37	19.30	9.00	8.90	16.71	17.57
T ₃	19.09	19.70	9.04	9.30	17.14	17.70
T ₄	17.69	18.45	8.61	9.19	16.08	16.18
T ₅	18.17	19.00	8.70	9.22	16.51	17.41
SEm(±)	0.53	0.69	0.26	0.26	0.41	0.55
LSD (<i>p</i> = 0.05)	NS	NS	NS	NS	NS	NS
Weed management in rice						
W ₁	14.56	14.50	6.59	6.56	13.16	13.00
W ₂	14.76	15.39	7.08	7.10	14.29	14.90
W ₃	21.09	22.18	10.82	11.44	19.10	19.82
W ₄	22.09	22.88	10.32	11.00	19.41	19.89
SEm (±)	0.41	0.47	0.22	0.16	0.37	0.40
LSD (<i>p</i> = 0.05)	1.18	1.64	0.67	0.53	1.11	1.25
Interaction						
Factor B at same level of A	NS	NS	NS	NS	NS	NS
Factor A at same level of B	NS	NS	NS	NS	NS	NS

Table.3 Effect of weed management practices on NPK uptake by grain and straw of direct seeded basmati rice preceded by wheat

Treatment	Grain (kg/ha)						Straw (kg/ha)						
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	
Weed management in wheat													
T ₁	26.2	25.6					15.3	15.0	11.3	11.1	44.6	44.1	
	8	4	8.33	8.28	9.15	9.00	8	0	9	0	6	6	
T ₂	28.8	31.9		10.4		11.7	16.1	18.4	12.3	13.5	47.6	50.6	
	3	4	9.07	0	9.77	2	5	2	9	9	1	8	
T ₃	29.0	32.9				10.2	12.7	17.4	18.4	13.1	14.0	50.0	52.2
	5	7	9.34	9.90	7	8	9	5	7	6	0	3	
T ₄	27.0	29.1				10.6	15.9	16.7	12.2	12.7	44.8	47.0	
	2	1	8.53	8.82	9.04	2	8	7	6	3	1	5	
T ₅	27.4	30.7				10.8	15.7	16.8	12.3	13.4	45.4	48.1	
	3	6	8.84	9.00	9.47	3	4	7	7	7	0	4	
SEm(±)	2.37	1.19	0.23	0.35	0.36	0.30	0.59	0.99	0.55	0.85	1.55	2.79	
LSD (p= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Weed management in rice													
W ₁	15.9	14.7									27.5	24.2	
	4	8	4.25	3.29	4.95	4.75	8.87	8.22	6.43	5.74	2	8	
W ₂	19.9	21.8					11.5	12.4			34.0	35.9	
	7	8	6.43	6.56	6.81	8.25	0	4	9.09	9.13	9	9	
W ₃	36.6	40.2	11.8	13.0	12.7	14.9	21.3	23.5	16.3	18.3	59.9	65.8	
	3	5	8	5	6	2	4	1	5	5	7	9	
W ₄	38.3	43.4	12.7	14.0	13.6	15.7	22.8	24.2	17.3	18.7	64.4	67.6	
	5	4	3	6	3	2	8	3	9	5	0	5	
SEm (±)	0.65	0.92	0.25	0.30	0.29	0.32	0.45	0.48	0.42	0.46	1.33	1.39	
LSD (p= 0.05)	2.28	3.22	0.88	1.05	1.02	1.02	1.58	1.27	1.12	1.61	4.46	4.33	
Interaction													
Factor B at same level of A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Factor A at same level of B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table.4 Effect of weed management practices on NPK uptake by weeds at 30 DAS and Harvest in direct seeded basmati rice preceded by wheat

Treatment	30 DAS						At harvest					
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium	
	(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)	
	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂	KY ₁	KY ₂
Weed management in wheat												
T ₁	4.05	4.22	1.95	2.04	3.93	3.95	16.83	18.97	7.22	7.41	16.15	17.44
T ₂	3.26	3.21	1.56	1.60	3.15	3.12	15.43	15.04	6.56	6.50	14.97	14.27
T ₃	3.19	3.00	1.52	1.50	3.07	2.98	14.63	14.60	6.22	6.06	14.28	14.15
T ₄	3.55	3.26	1.71	1.68	3.40	3.06	16.75	16.24	7.21	6.79	16.03	16.00
T ₅	3.48	3.49	1.62	1.60	3.34	3.27	15.61	15.58	6.58	6.56	15.51	15.47
SEm(±)	0.25	0.18	0.12	0.09	0.27	0.18	1.53	1.13	0.66	0.44	1.46	1.09
LSD(p= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management in rice												
W ₁	5.74	6.03	2.74	3.03	5.54	5.86	35.67	37.50	15.08	15.66	34.40	35.96
W ₂	5.60	5.49	2.67	2.65	5.37	5.18	15.06	14.80	6.53	6.04	14.79	14.36
W ₃	1.34	1.05	0.68	0.56	1.36	1.12	7.20	6.89	3.17	2.76	6.90	6.57
W ₄	1.38	1.17	0.65	0.51	1.30	1.01	5.53	5.11	2.38	2.12	5.40	5.02
SEm (±)	0.22	0.17	0.11	0.11	0.21	0.13	1.33	1.12	0.57	0.46	1.28	1.10
LSD (p= 0.05)	0.66	0.59	0.35	0.39	0.65	0.39	4.65	3.39	1.72	1.39	3.97	3.36
Interaction												
Factor B at same level of A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor A at same level of B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The superior control of weeds by the pre-emergence application of pendimethalin @ 1.0 kg/ha and the sequential application of pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.030 kg/ha (PoE) caused substantial reduction in crop-weed competition with respect to soil moisture, nutrients, sunlight and space at the very beginning of the crop growth leading to significant improvement in all the growth parameters, yield attributes and yields of the crop. The pre-emergence imposition of pendimethalin @ 1.0 kg/ha provided ample suppression of multiple weed flora up to 30 days, however, the smaller number of weeds that appeared in the latter flushes were effectively controlled by the post-emergence application of bispyrebac @ 0.030 kg/ha. Although, bispyrebac @ 0.030 kg/ha applied after pendimethalin @ 1.0 kg/ha as post-emergence herbicide recorded enhancement in crop yields numerically but remained statistically at par to the sole application of pendimethalin @ 1.0 kg/ha (PE). Since, after the pre-emergence application of pendimethalin @ 1.0 kg/ha the latter emergence of weeds at 30 DAS were not enormously high that could have caused substantial variation in the growth, yields and yield attributes of the crop as a result the plots received treatment of either pendimethalin @ 1.0 kg/ha alone or pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.030 kg/ha (PoE), gave statistically comparable results.

On the other hand, critical crop-weed competition period had already commenced in the treatment plots that received mechanical weedings (at 30 and 60 DAS), as a consequence of the competition imposed by the weeds at the very outset the growth of the crop was reduced initially causing an overall reduction in yield and yield attributes besides mechanical weeding in direct seeded rice did not provide satisfactory control of weeds. However, at latter stages crop recovered to some extent after the application of second

mechanical weeding at 60 DAS but crop yields remained significantly lower than that attained with the application of pendimethalin @ 1.0 kg/ha (PE) as well as pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.030 kg/ha (PoE). These results are in agreement with the findings of Kumaran *et al.*, (2015). However, mechanical weedings twice at 30 and 60 DAS recorded significantly higher yield and yield attributes compared to weedy check. Similar findings that support the use of herbicides as the most effective means of securing higher rice yields in comparison to mechanical weedings were reported by Cherati *et al.*, (2011); Badiyala *et al.*, (2014); Kumaran *et al.*, (2015) and Prasuna and Rammohan (2015). Similar findings were recorded in the second year of research trial with the only difference that all the weed management treatments registered marginal increase in crop yields while the reverse trend was noticed under continuous weedy conditions prevailing in the weedy check plots where a little decline in grain and straw yields was noticed. Interaction effects obtained by the weed management treatments in both wheat and rice with regard to the grain and straw yields of direct seeded basmati rice were found to be non-significant.

Nutrient uptake by direct seeded basmati rice

Nutrient uptake in terms of N, P and K was estimated on the basis of plant dry matter production and there is a close relationship between the total uptake of nutrients with the grain and straw yields of the crop. The results of nutrient estimation presented in table 2 and 3 with regard to N, P and K reveals that in main plots wherein different weed management treatments applied on the preceding wheat crop had non-significant influence on the nutrient uptake by DS basmati rice plants at 30 DAS and also by the grain and straw of the DS basmati rice crop.

However, these treatments had significant influence on the nutrient uptake by the preceding wheat crop, its detailed information is not provided here as the focal point here is the direct seeded basmati rice. A numerical trend in the nutrient removal by the grain and straw of the DS basmati rice in the main plots was observed in decreasing order under corresponding treatments T₃ (isoproturon @ 1.0 kg/ha + 2, 4-D @ 0.500 l/ha -PoE); T₂ (mechanical weedings twice at 30 and 60 DAS); T₅ (triasulfuron @ 0.015 kg/ha -PoE); T₄ (clodinafop @ 0.060 kg/ha -PoE) and T₁ (weedy check), respectively.

On the other hand in sub plot treatments, nutrient uptake by the direct seeded basmati rice at 30 DAS was significantly influenced by all the weed management treatments applied to the crop except W₂ (mechanical weedings at 30 and 60 DAS) in which nutrient content in rice plants was statistically at par with that obtained in W₁ (weedy check). The highest values of N, P and K uptake by basmati rice plants at 30 DAS obtained under W₄ (pendimethalin @ 1.0 kg/ha-PE *fb* bispyrebac @ 0.030 kg/ha -PoE) were (N 22.09 and 22.88 kg/ha; P 10.32 and 11.00 kg/ha; K 19.41 and 19.89 kg/ha) during both *kharif* seasons of 2014 and 2015, respectively. This statistical similarity between treatment of mechanical weeding (W₂) and weedy check (W₁) at 30 DAS is because of the fact that first mechanical weeding was applied at 30 DAS, thus till 30 days the crop did not receive any treatment consequently uniform conditions of undisturbed weed growth prevailed between the plots of mechanical weedings and weedy check. On the other hand, efficient control of weeds by the pre-emergence application of pendimethalin @ 1.0 kg/ha under both treatments W₃ (pendimethalin @ 1.0 kg/ha-PE) and W₄ (pendimethalin @ 1.0 kg/ha-PE *fb* bispyrebac @ 0.030 kg/ha -PoE) significantly reduced the biomass of weeds thereby more nutrients

were available to the crop consequently higher nutrient removal by the direct seeded crop was noticed at 30 DAS. Similar findings were reported by Sharma (2015).

Identical results were obtained in the succeeding rice crop in the second year of experimentation, however, a marginal increase in nutrient uptake by basmati rice plants at 30 DAS was noticed with all weed management treatments while this parameter was found to be slightly lesser under continuous weedy conditions under weedy check plots compared to the previous crop of *kharif* 2015. Interaction effects were found to be non-significant.

All the weed management treatments applied in direct seeded basmati rice crop significantly influenced nutrient uptake by rice grain and straw over weedy check. Significantly highest nutrient removal by grain and straw of rice was recorded under W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE), which was, however, statistically at par to the second best treatment W₃ (pendimethalin @ 1.0 kg/ha -PE). The corresponding values of N, P and K uptake by basmati rice grain under registered under W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE) were (N 38.35 and 43.44 kg/ha; P 12.73 and 14.06 kg/ha; 13.63 and 15.72 kg/ha) during both *kharif* seasons of 2014 and 2015, respectively. On the other side, the highest removal of N, P and K by rice straw was observed under the same treatment W₄ with values N 22.88 and 24.23kg/ha; P 17.39 and 18.75 kg/ha; K 64.40 and 67.65 kg/ha recorded in both *kharif* seasons of 2014 and 2015, respectively. The possible reasons ascribed to the higher weed control efficiency with these superior herbicidal treatments resulting in favourable environment for growth and development of the crop due to lesser weed competition that led to the increased crop growth with regard

to plant height, leaf area index and dry matter accumulation resulting better yield attributes thereby higher accumulation of nutrients in rice grain and straw was observed. These experimental outcomes are in close conformity to the findings of Singh and Singh (2010); Brar and Bhuller (2013). Almost similar trend was observed in the second year of cropping during *kharif* 2015 with the only distinction that under all weed management practices slightly higher nutrient removal by the rice grain and straw was noticed while marginal decrease in the same was recorded under undisturbed weedy conditions in weedy check plots compared to the preceding crop. Non-significant interaction effects were observed with regard to nutrient uptake by the grain and straw of rice.

Nutrient removal by weeds as influenced by weed management treatments in direct seeded basmati rice preceded by wheat

It is apparent from the data on nutrient uptake in terms of N, P and K by weeds at 30 DAS and at crop harvest stage presented in table 4 that the main plot weed management treatments which were applied in the previous wheat crop showed non-significant effect on the nutrient extraction by weeds at 30 DAS and at crop harvest stage.

As mentioned earlier these treatments had significant effect on the nutrient removal by the weeds of preceding wheat crop but not discussed in detail here as the main emphasis in this study is on direct seeded basmati rice crop. However, numerically the lowest to highest values of nutrient uptake by weeds at 30 DAS and at harvest were recorded under corresponding treatments T₃ (isoproturon @ 1.0 kg/ha + 2, 4-D @ 0.500 l/ha -PoE); T₂ (mechanical weedings twice at 30 and 60 DAS); T₅ (triasulfuron @ 0.015 kg/ha -PoE); T₄ (clodinafop @ 0.060 kg/ha -PoE) and T₁ (weedy check), respectively.

In the sub plots, all the weed management treatments imposed on DS basmati rice for the control of weeds recorded significant reduction in the nutrient uptake by weeds at 30 DAS except W₂ (mechanical weedings at 30 and 60

DAS) wherein nutrient removal by weeds was statistically at par with that of W₁ (weedy check). Further, at 30 DAS, significant reduction in nutrient extraction by weeds was noticed under W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE), however, statistically at par with W₃ (pendimethalin @ 1.0 kg/ha -PE). This statistical equivalence between afore cited treatments is because of the reason that the first mechanical weeding was applied at 30 DAS, thus till 30 days similar weedy conditions prevailed in the plots of mechanical weedings and weedy check. On the other hand, application of pendimethalin @ 1.0 kg/ha (PE) *fb* bispyrebac @ 0.030 kg/ha (PoE) and pendimethalin @ 1.0 kg/ha (PE) produced statistically similar results in lessening nutrient uptake by weeds at 30 DAS because bispyrebac @ 0.030 kg/ha was applied at 30 DAS, therefore, in both the treatment plots only pendimethalin @ 1.0 kg/ha (PE) was applied till 30 DAS. Consequently, reduction in nutrient removal by weeds was by and large was similar in both treatment plots. Efficient control of weeds by the pre-emergence application of pendimethalin @ 1.0 kg/ha significantly decreased the dry matter accumulation of weeds causing decreased nutrient removal by weeds at 30 DAS. These results are corroborative to the findings of Kumaran *et al.*, (2015).

On the other hand, at crop harvest stage, all the weed management treatments applied to DS basmati rice crop significantly reduced the nutrient removal by weeds compared to weedy check. At this stage, significantly, lowest uptake of nutrients by weeds was recorded under W₄ (pendimethalin @ 1.0 kg/ha -PE *fb* bispyrebac @ 0.030 kg/ha -PoE), which was, however, statistically at par to the following best treatment of W₃ (pendimethalin @ 1.0 kg/ha -PE). This was due to the fact that efficiency of the weed control treatments and the nutrient uptake by weeds have negative correlation. Similar findings were reported by other researchers (Brar and Bhuller, 2013; Narolia *et al.*, 2014; Kumaran *et al.*, 2015).

By and large similar results were obtained in the second year of cropping with the only variation that all the weed management interventions recorded slightly lower nutrient removal by weeds while weeds in weedy check plots registered marginally higher nutrient uptake compared to the first year of *kharif* 2014. Non-significant interaction effects were observed with regard to nutrient uptake by weeds both at 30 DAS and at crop harvest.

It can be concluded from the experimental results that there was direct correlation of weed control practices on the crop yields and nutrient removal by both crop and weeds. The weed management treatments that provided superior control of weeds resulted in the higher crop yields and effected higher removal of N, P and K nutrients by the crop plants vis-à-vis lower uptake of these nutrient elements by the weeds present in direct seeded basmati rice crop.

Efficient control of weeds resulted in favourable environment for growth and development of the crop due to lesser weed competition that led to the increased crop growth with regard to plant height, leaf area index and dry matter accumulation resulting better expression of yield attributes culminating into higher crop yields all these factors resulted in higher removal of nutrients by the DS basmati rice crop besides lower uptake of these nutrients by weeds.

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